Rates of Delivery of Organic Carbon and Nutrients to the Hypoxic Region of Lake Erie

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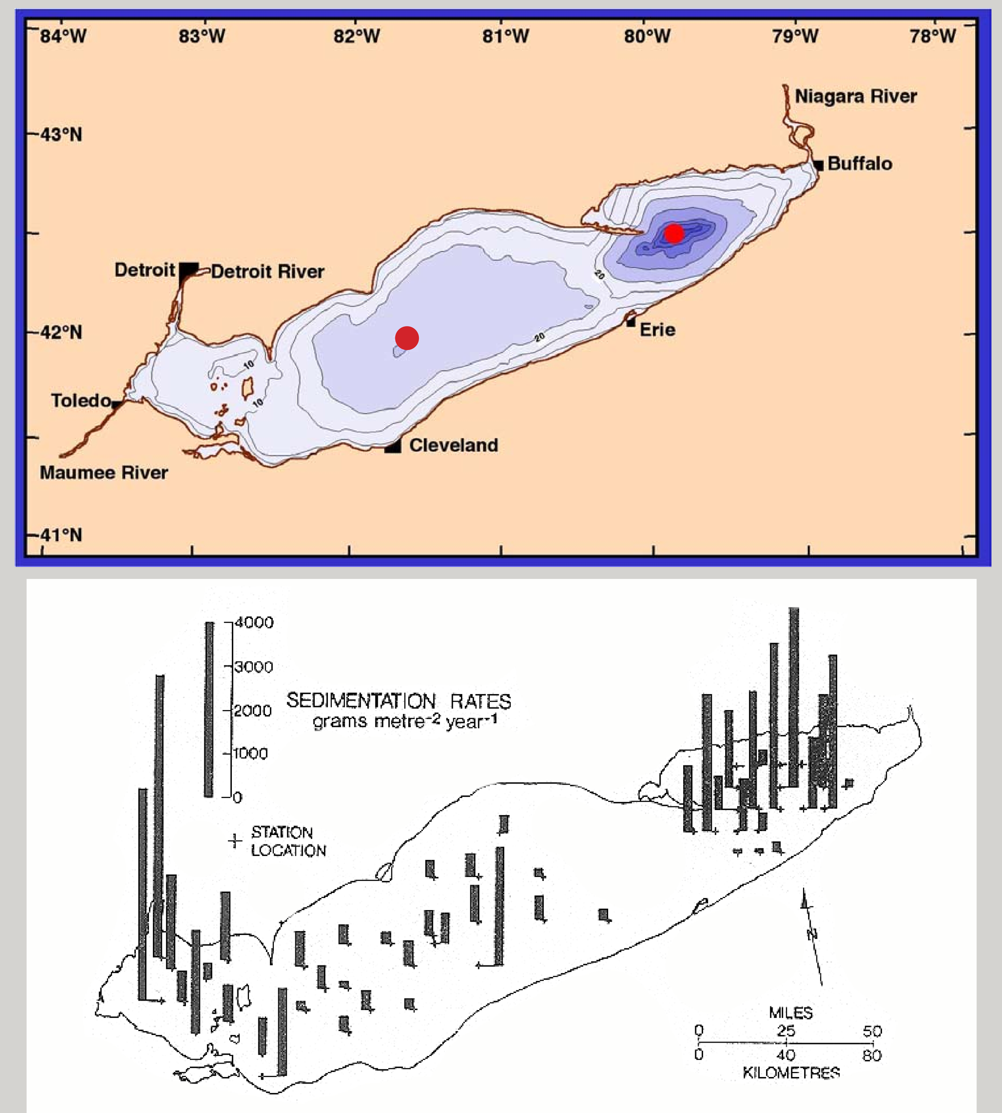
INTRODUCTION

Lake Erie is unique in several ways among the Laurentian Great Lakes. In this study, we explore the rates of delivery of mass and nutrients in two of these areas. The Central Basin, where a shallow hypolimnion leads to annual summer anoxia/hypoxia, and the deep hole in the Eastern Basin where sediments accumulate at a greater rate than anywhere else in the open Great Lakes.

The central basin (CB) hypolimnion of Lake Erie generally exhibits hypoxia, and occasionally anoxia, at the end of the summer, with equilibrium saturation of O_2 re-established during the late winter – early spring when vigorous mixing occurs within the isothermal water column. In an attempt to eliminate the low levels of dissolved oxygen, phosphorus loads to the lake were reduced through regulation and subsequently lake TP declined until about 1995. A cause of current concern is that recent monitoring data imply that lake phosphorus concentrations are increasing from the low values in the mid-1990s.

Being the shallowest of the Great Lakes, Erie has frequent and extensive sediment resuspension events and is thus tightly coupled to the legacy of nutrients and contaminants stored in exchangeable sediments. In this study, sediment traps were deployed at a depth of 5m above the bottom in the central and eastern basins (recipient of transport from the CB) to measure the rates of delivery of mass, organic matter and nutrients. The trap moorings were deployed adjacent to moorings equipped with a vertical profile of transmissometers and a bottom-mounted ADCP. The moorings covered the period from mid-April 2004 through mid-April 2005.

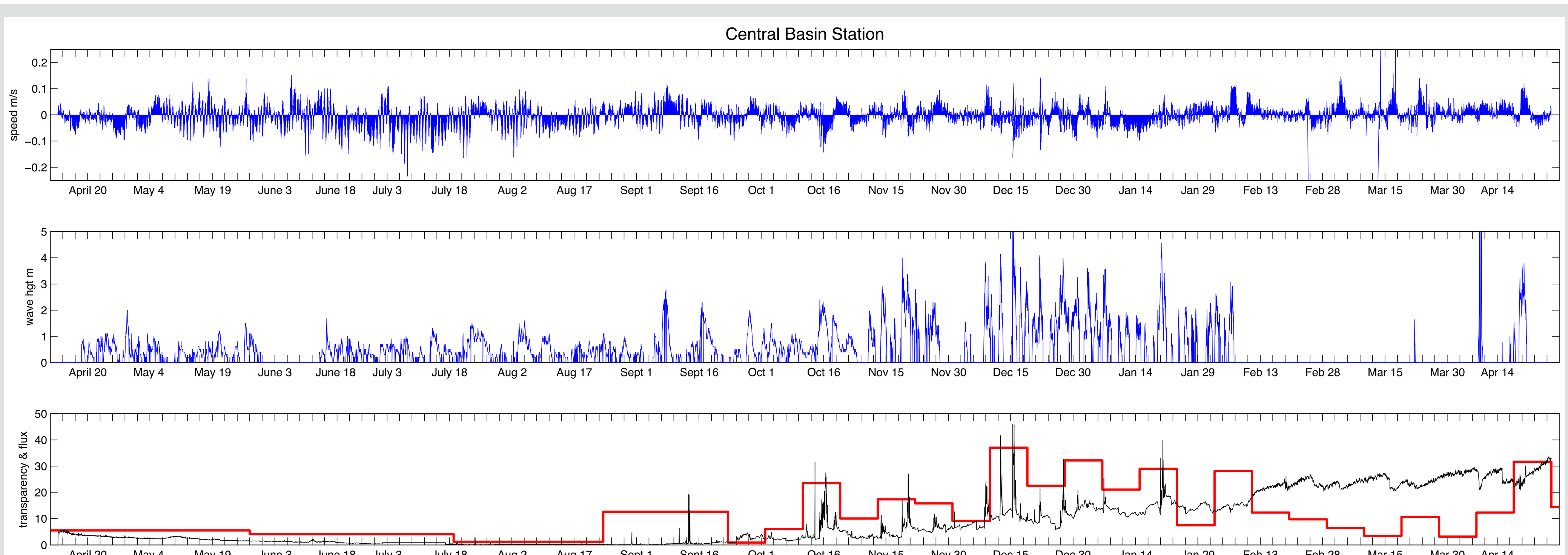


The station locations are shown in the upper panel along with lake bathymetry. The lower panel represents sediment accumulation rates based on the horizon of ragweed pollen (Kemp et al. 1977).

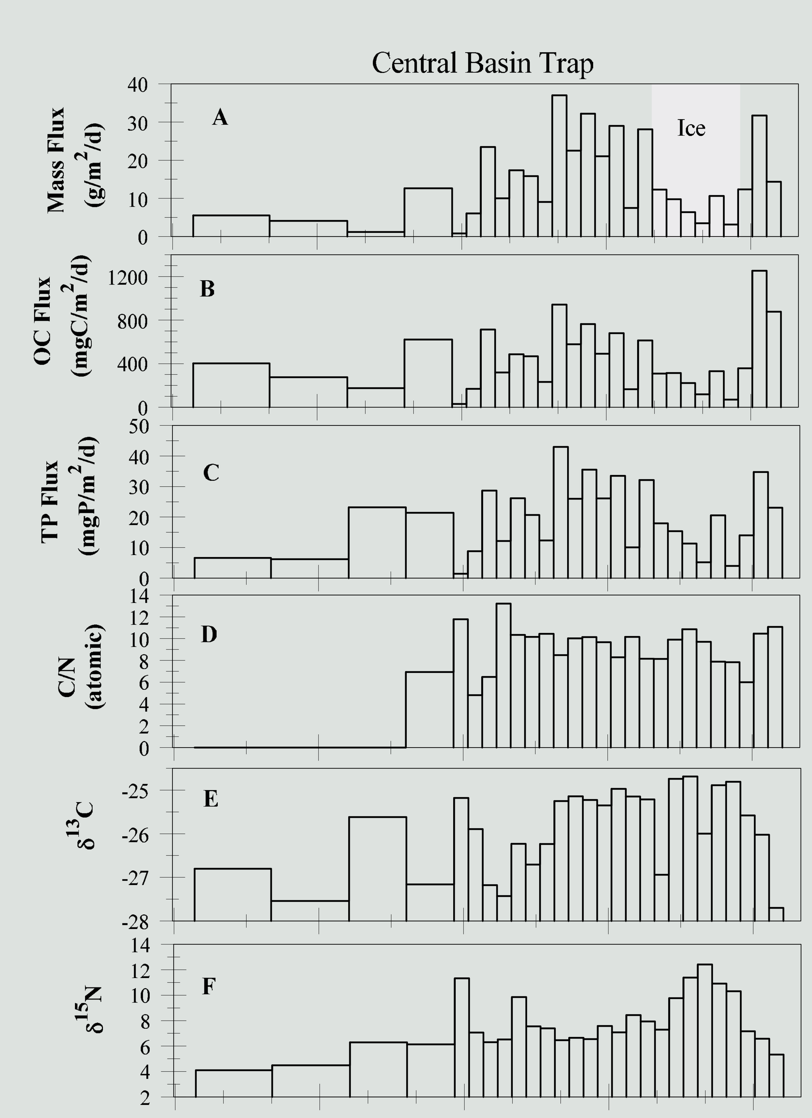
A MODIS image from January 2006 clearly illustrating sediment resuspension and the input from bluff erosion along the northshore.

Site Comparisons: Traps and Local Sediment Accumulation

	CB Traps	CB Sediment	EB Traps	EB Sediment
Depth (m)	25		56	
Trap mass flux ($g/cm^2/y$)	0.42	0.07	0.17	0.11
OC flux ($mgC/cm^2/y$)	15.4	2.1	3.9	1.6
TP flux ($mgP/cm^2/y$)	0.64	0.07	0.17	0.01
$\delta^{13}C$ (average)	-25.9	-24.8	-25.3	-25.8
$\delta^{15}N$ (average)	7.7	8.4	8.5	7.8



Time series data from near bottom in the Central Basin. The upper panel illustrates currents, the middle panel shows wave heights, and the bottom panel has both transmissometry and trap mass flux measurements. The upward drift in the transmissometer data (winter 2005) is a result of fouling.



RESULTS - Central Basin

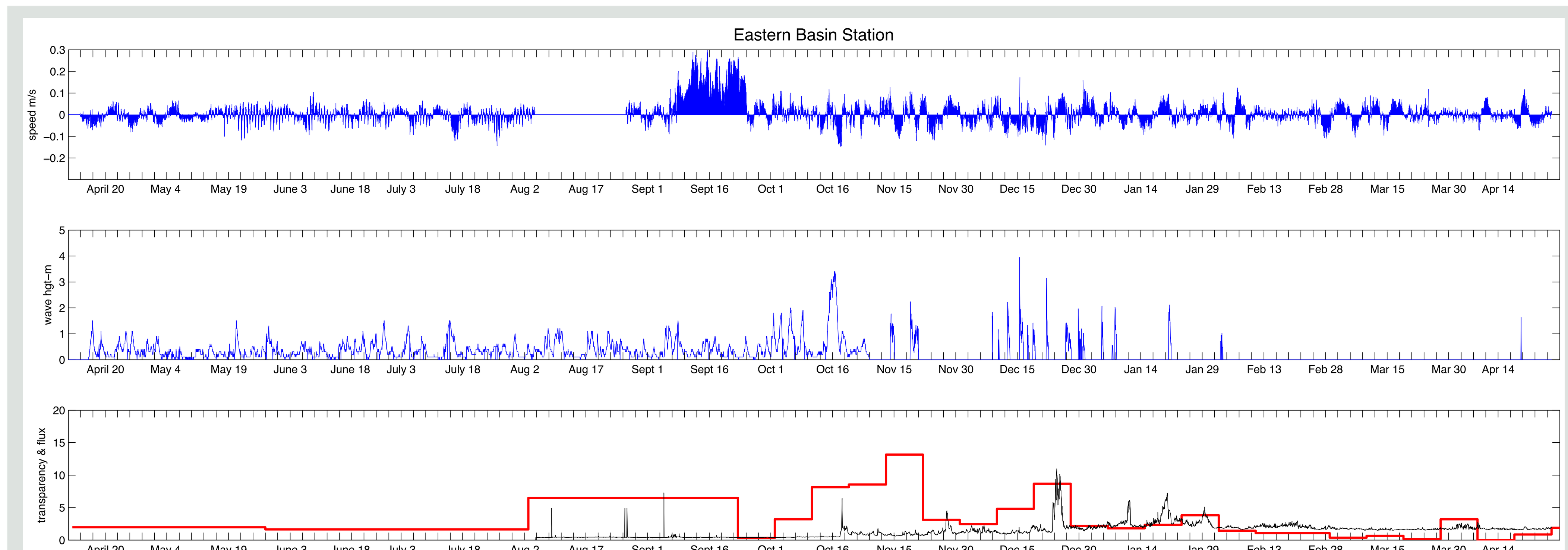
A: CB fluxes ranged from 0.8 to 37 $g/m^2/d$ over 9 day collection intervals, with peaks in the fall-early winter, declining to a minimum after ice covers the lake (shaded area). Higher fluxes reappear after ice out in the spring. Pulses in the transmissometer record clearly illustrate that the elevated fluxes recorded in the traps often correspond to brief events. During the ice covered period the fluxes gradually declined over a period of a month. Since there was no wave activity during the ice-covered period, this decline provides an estimate of the overall settling times for the water column particle pool.

B: The mean mass flux of 11.6 $g/m^2/d$ had an average of 3.2% organic carbon resulting in an average organic carbon flux of 423 $mgC/m^2/d$. The OC concentration ranged from 2.2 to 4.0 %, with the highest values in April 2005. Lowest concentrations were in January. These concentrations are similar to values measured over the years in surface sediments within approximately 2 miles of the trap location (2.4 – 3.2 %).

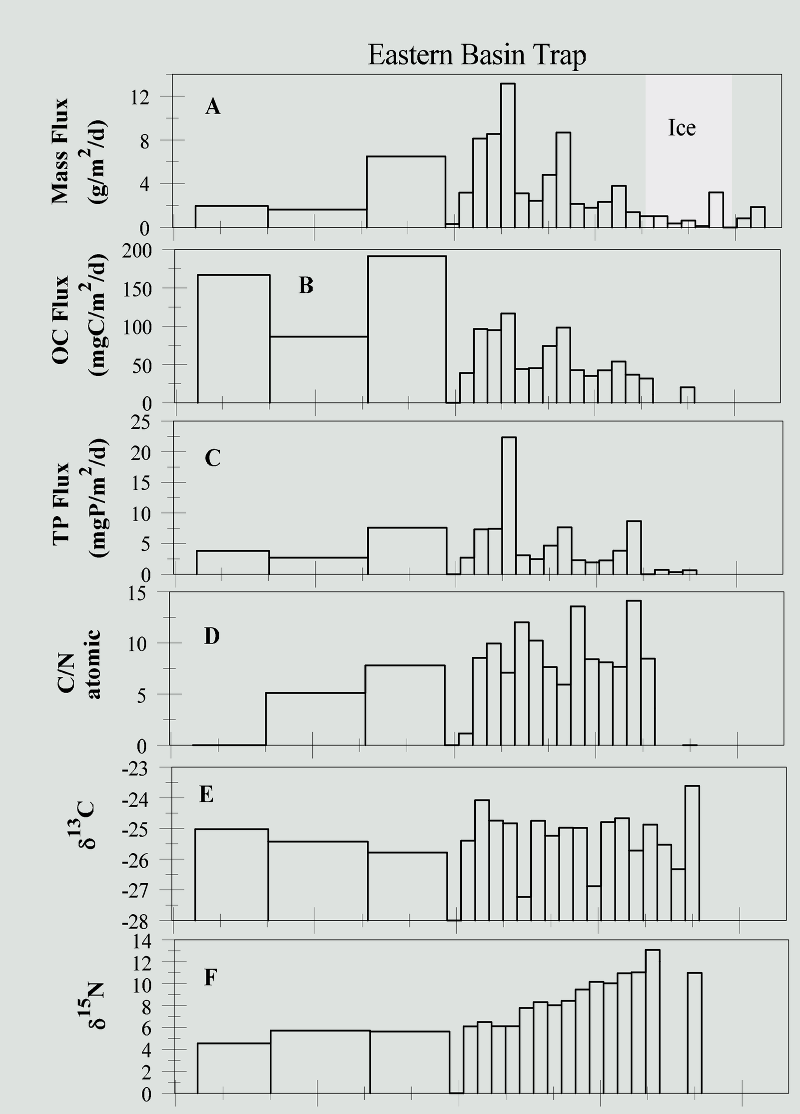
C: The average flux of total P was 17.5 $mgP/m^2/d$. TP concentrations ranged from 1.1 to 1.9 mgP/g and were highest in February. Lowest concentrations were in December and January, similar to the organic carbon. The TP concentrations were all higher than sediment measurements (.95 to 1.0).

D: C/N was highest in the fall (10–13) and lowest (6-10) in the winter. The low winter values are near the Redfield value for autochthonous production. The higher values represent values similar to nearby sediments (9) or a contribution from terrestrial materials which generally have values over 20.

E/F: The isotopic composition of the trapped material shows a strong seasonal signal. The $\delta^{13}C$ is lightest from spring into the fall and then gets progressively heavier (approaching the nearby surface sediment value of -24.8) until the following spring. The $\delta^{15}N$ values are light in the spring then get heavier beginning in late summer. The values approach the surface sediment value of 8.4. However, in winter, when the lake is iced-over the values increase to over 10. This corresponds to the collection periods when the fluxes are declining over a month after ice coverage. The heavy $\delta^{15}N$ values may correspond to a particle sorting where the most slowly settling have a very heavy $\delta^{15}N$.



Time series data from near bottom in the Eastern Basin. The upper panel illustrates currents, the middle panel shows wave heights, and the bottom panel has both transmissometry and trap mass flux measurements.



RESULTS - Eastern Basin

A: EB fluxes ranged from 0.3 to 13 $g/m^2/d$ over 9 day collection intervals, with peaks in the fall-early winter, and decline to a minimum after ice covers the lake. As in the Central Basin, higher fluxes reappear after ice out in the spring. Pulses in the transmissometer record at this station do not correlate with elevated fluxes recorded in the traps. There are both high mass fluxes without transmissometer peaks, as well as intervals of peaks in the transmissometer record where trap fluxes are low. During the ice covered period the fluxes gradually declined over a period of a month, again providing an estimate of the overall settling times for the water column particle pool.

B: The mean mass flux of 4.6 $g/m^2/d$ had an average of 2.3 % organic carbon resulting in an average organic carbon flux of 107 $mgC/m^2/d$. The OC concentration ranged from 0.9 to 8.5 % with the highest values in April-May 2004. Lowest concentrations were in October. These concentrations are higher than values measured over the years in surface sediments within approximately 2 miles of the trap location (1.3–1.5 %).

C: The average flux of total P was 4.7 $mgP/m^2/d$. TP concentrations ranged from 0.7 to 1.9 mgP/g and were highest in April-May 2004. Lowest concentrations were in October, similar to the organic carbon. The average TP concentrations in the traps (1.0 mgP/g) were similar to the sediment measurements (0.90 mgP/g).

D: C/N was highest in late fall (10–13) and lowest (7-8) in the winter. The low winter values are near Redfield for autochthonous production. The higher values represent values similar to sediments (8.2) or a contribution from terrestrial materials which generally have values over 20.

E/F: At this station, the isotopic composition of the trapped material does not show a seasonal signal. The $\delta^{13}C$ is relatively constant throughout the year, and averages (-25.3) close to the surface sediment (-25.8). The $\delta^{15}N$ pattern at this station is similar to the Central Basin site. Values are light in the spring then get heavier beginning in late summer. The values approach the surface sediment value of 7.8. However, in winter, when the lake is iced-over the values increase to over 10. This corresponds to the collection periods when the fluxes are declining over a month after ice coverage.

SUMMARY

Lake Erie has a hydraulic residence time of less than 2 years. There are multiple sources of materials to the sediments and traps. Tributary inputs, primarily from the western end, move eastward, along with large inputs of eroded materials from the northshore bluffs. These inputs undergo transformations as they are transported toward the Central Basin via resuspension and transport events. The Eastern basin receives this processed material again as a result of resuspension and transport events, along with extensive bluff erosion from the northshore and Long Point. These eroded materials are low (~0.2%) in organic carbon. We plan to use the analyses presented here along with neutron activation analysis to see if sources for these sites can be discriminated.

From the preliminary data, the CB near-bottom trap accumulates more mass than the deep EB site, although the sediments accumulate more rapidly at the EB site. The difference between the trap and sediment accumulation was much larger at the CB site, implying extensive local resuspension. The same applies to both organic carbon and total phosphorus fluxes. C/P for both traps is approximately 24, while the C/P for sediments at the CB is 30 and for the EB is over 100. This implies that the trap organic matter is less degraded, likely a contribution from freshly settling materials